

# 2138 Impact of Bt-cotton on Agriculture in India

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## Abstract

Bt cotton was approved for commercial cultivation in India in March 2002 after stringent assessment for biosafety and profitability. The Bt-cotton area increased from a meager 0.4% to 40% of the cotton area in India, in a short period of four years. The technology was found to result in many positive benefits for Indian agriculture, especially in terms of reducing farmer stress from management issues related to the menacing cotton bollworm. Though other benefits of yield increases and pesticide reduction were apparent in majority of areas, some farmers and NGOs were raising concerns constantly from time to time. One of these was the spread of 'illegal Bt-cotton' varieties, which were untested and unapproved for biosafety, but were being clandestinely cultivated by farmers in some parts of the country. One clear impact of Bt-cotton on Indian agriculture appears to be the replacement of large tracts of varietal areas of north India, with Bt-hybrids, since the technology is available in India only in the form of hybrids. Bt-cotton seems to have reduced the overall quantity of insecticide substantially, only in some parts of the country, especially coupled with spectacular yield increases reported from one particular state called Gujarat, while rest of the states have been showing mixed results despite increase in the area under Bt-cotton. Secondary insect pests such as mirid bugs (*Creontides biseratence*), were found to increase to damaging numbers in unsprayed cotton fields. The tobacco caterpillar, *Spodoptera litura*, was also found to stage a come back as an economic pest of Bt-cotton. Data showed that thus far there are no symptoms of resistance to Cry1Ac in any of the bollworm field populations tested. Recently two additional events comprising of a truncated version of Cry1Ac and Cry1Ac+Cry2Ab (Bollgard-II) were approved for cultivation. The new genes are expected to be more useful in introducing genetic variability in the available transgenes so that minor pests and resistance can be management effectively.

## Introduction

India has the largest cotton area in the world with about 90 lakh hectares accounting for one-fourth of the global cotton area. It contributes to 16% of the global cotton produce and ranks third after the United States and China. Cotton contributes 29.9% of the Indian agricultural gross domestic product and provides livelihood to nearly 6 crore people with half of this population employed directly by the textile industry. There are more than 17 lakh registered looms, 1500 spinning units and an estimated 280 composite mills. The textile industry contributes 4% to total GDP, 30.0% to agricultural GDP, 14% to industrial production and 27% to export earnings. Therefore cotton is considered to be one of the crops that are immensely important for the sustainable economy of the country and livelihood of the Indian farming community. GM crops are being considered to have immense potential in improving production, productivity and environmental safety for the country.

## Biosafety assessment and approval

India has a well-defined system comprising of six committees constituted by the Government of India to evaluate biosafety and regulate GM crops. Two of these, the

Recombinant DNA Advisory Committee (RDAC) and the Review Committee on Genetic Manipulation (RCGM) are under the Department of Bio-technology. The main approving body, the Genetic Engineering Approval Committee (GEAC) is under the Ministry Environment and Forests. The Institutional Biosafety Committee (IBSC) is internal to technology developers and prepares site-specific plans for use of genetically engineered microorganisms. The RCGM lays down procedures/regulations regarding conducting and monitoring research, production, sale, import and use of genetically engineered organisms with a view to ensure environmental safety, while the GEAC finally approves the release of genetically engineered organisms into the environment. The State Bio-technology Coordination Committees (SBCC) and the District Level Committees (DLC) inspect, investigate and take punitive action in case of violations of safety and control measures in the handling of genetically engineered organisms.

The development of Bt cotton in India from the transgenic cotton of Monsanto, USA, underwent a stringent regulatory process before it finally reached farmer fields. Mahyco had obtained 100g of Coker 312-Bt (Cry1Ac)-cotton seed from Monsanto USA, in 1996. Biosafety tests indicated absolute safety to goats, cows, buffaloes, fish and poultry. Feed-safety studies with Bt cottonseed meal were carried out with goats, buffaloes, cows, rabbits, birds and fish. The results revealed that the animals fed with Bt-cotton seed meal were comparable to the control animals in various tests and showed no ill-effects. Field trial results showed good boll retention and higher yields. Apart from the increase in yields there was a concomitant reduction in the use of insecticides due to Bt-cotton. Thus it was concluded that Bt-cotton has potential to improve the lives of cotton farmers through the provision of favourable environmental and economic consequences and subsequently released in 2002 for commercial cultivation. Since then, the area under Bt cotton increased from 29,307 hectares in 2002 to 3,800,000 hectares during 2006.

### **Stewardship and post release monitoring of the GM crop**

Recently two more Cry1Ac events, developed in India and China, were released. From biosafety perspective, the most imminent challenge for developing countries like India is the need to develop GMO detection kits based on generic markers and specific transgene inserts to ensure an adequate level of protection in the field of safe transfer, handling and use of LMOs/GMOs taking also into account risks to human health, and specifically focusing on trans-boundary movement. India is a party to the Cartagena Protocol on Biosafety under the Convention on Biological Diversity (CBD), which is an attempt to establish a globally harmonized regime for biosafety especially enabling countries to regulate trans-boundary movement of transgenes. Currently, GMO detection kits to enable regulate trans-boundary movement are unavailable in the country. Technology for reliable detection of unapproved events and unapproved varieties is not as yet available in the country. Therefore efforts are being directed to ensure the development of all such protocols that can ensure detection of all GM products and their effects so as to regulate environmental biosafety of the country.

### **Performance and economic benefits**

Large scale cultivation of Bt cotton has resulted in the significant reduction of insecticide use to the tune of 40 to 60% less than the intensity on the corresponding non-transgenic varieties. Several studies have evaluated the economic benefits accrued due to the cultivation of Bt transgenic cotton versus the corresponding non-transgenic cultivar. Apart from causing a reduction in the usage of insecticides all over the world Bt-cotton has significantly contributed to enhanced yields. Hence it has become very popular in all cotton growing countries of the world. One important advantage of Bt-cotton is that farmers rarely

resort to prophylactic spray applications, which they do otherwise, in the absence of Bt-technology. In some regions of the country 7-10 prophylactic sprays per season are common on cotton. The total number of sprays averaged at 16-20 in some districts of Andhra Pradesh and Punjab during 1986-2001. Recent reports (Qaim and Zilberman., 2003; Barwale et al., 2004; Bennet et al., 2004, Morse et al., 2005) showed that yields increased substantially by adopting Bt-cotton and farmers in India were able to reduce at least 2-3 insecticide applications.

Qaim and Zilberman (2003) reported data from field trials conducted by Mahyco during 2001, in 157 farms in 25 districts of Madhya Pradesh, Maharashtra and Tamilnadu. The data showed that there were no changes in the insecticide use for sucking pest control, but at least 3 spray applications meant for bollworm control were saved due to the Bt-technology. Thus, insecticide use of cotton bollworm was reported to have been reduced by 83% and yield increase by a staggering 80%. The study was widely criticised (Arunachalam and Bala Ravi, 2003; Sahai, 2003) for its lack of proper methodology. A report (Sahai and Rahman, 2003) published by the gene campaign shows that Bt-cotton yields were 15% lower than that of non-Bt-cotton in 100 fields of Maharashtra. Qayyum and Sakhari, (2005) found that Bt-cotton hybrids did not perform satisfactorily with 30% less yields in Bt-cotton, compared to non-Bt cotton, in the rainfed plots of 440 farms in four districts of Andhra Pradesh. However, Bennett et al., 2004 reported data that were supportive of the Qaim and Zilberman (2003) findings. Bennett et al., 2004 recorded data from 9000 farmers in 1,275 villages in Maharashtra during 2002 and 2003 to assess the economic advantage of Bt-cotton in India. They reported that on average, the use of bollworm sprays was 72% and 83% lower for Bt than for non-Bt plots in 2002 and 2003 respectively, with a corresponding reduction in expenditure per hectare. Yields of the Bt varieties were significantly higher than those of the non-Bt types. In 2002, the average increase in yield for Bt over non-Bt was about 45%, while in 2003 this increased to 63%. The average gross margin gap between Bt adopters and nonadopters was larger in 2003 (74%) than in 2002 (49%). Over the past four years bollworm infestation in India was low, thus reducing the need for insecticide applications. Comparitively, the benefits of Bt-cotton appear to have been more in other countries where bollworm infestation was high. Insecticide applications on Bt-cotton varieties were reduced up to 14 applications in China (Pray et al., 2002), 7 in South Africa and 5-6 in Indonesia and Australia (James, 2002).

### **Concerns expressed by farmers and NGOs**

Several concerns were expressed by NGOs and farmers from time to time. Some of them are: 1. Enhanced sucking pest damage in Bt-cotton. 2. Increase in secondary pests such as mired bugs and Spodoptera on Bt-cotton. 3. Bollworm survival on Bt-cotton and 4. wilt and low yields in Bt-cotton in some regions.

The Bt-cotton technology gives more than 70-80% protection against bollworms. Initially in the season it gives almost 100% control of the bollworm upto 80-85 days old crop. Later in the season about 10-20% insects can survive on the crop. Some plant parts such as the boll rind, square bracts, buds and flowers which express low levels of Cry1Ac, were found to sustain a small proportion of larvae that feed on them.

Bt-cotton is not at all toxic to any of the sucking pests of cotton. Since the donor parent Coker 312 is known to be highly susceptible to sucking pests such as jassids and thrips, the hybrids showed slightly enhanced susceptibility to these pests, especially if the recurrent parent did not possess inherent resistance to the sucking pests. The Bt-cotton currently released in India is only moderately toxic to the leaf eating caterpillar *Spodoptera*. Hence

farmers in some parts of the country found *Spodoptera* on Bt-cotton. It is known that the usage of synthetic pyrethroids had significant negative impact on the populations of *Spodoptera* and several other miscellaneous bugs such as the mirid bugs, *Creontiodes biseratence* (Distant). The reduction of pyrethroids and several conventional insecticides on Bt-cotton were expected to result in the increase of several non-target species.

A few newspaper reports and NGO surveys have been reporting that Bt-cotton failed in many parts of the country especially in rainfed regions. Clearly there has been a fair amount of confusion in drawing inferences from the crop failures and lack of Bt-cotton efficacy. Ever since the release of the Bt-technology, bollworm infestation in the country was at its lowest. It was to be expected that Bt-cotton would protect the crop from bollworms more efficiently if the pest pressures are high. Under low pest pressures the yield difference between Bt and non-Bt cotton would be minimum. The low yields in some pockets were clearly because of several biotic and abiotic reasons and had nothing to do with the failure of Bt-cotton to protect itself against bollworms.

Farmers were incorrectly associating Bt-cotton with parawilt. Parawilt was found to occur due to asphyxiation and can be more in Bt cotton plants because of higher boll retention. Farmers need to be educated that water, nutrient and soil management are extremely critical to get the best performance from Bt-cotton. Poor soils and rainfed conditions are not ideal for the performance of Bt-cotton. It needs optimum water and nutrients at a time when it holds maximum fruiting bodies including green bolls. Bt cotton does not withstand moisture and nutrient stress, especially because the boll retention capacity is much higher as compared to non-Bt varieties. Problems of wilt are generally reported commonly with Bt-cotton. It is true that wilt can be more in Bt-cotton as compared to non-Bt cotton. This is because of the high boll load in Bt-cotton crop.

### **Sustainability, resistance issues and geographical variability in tolerance.**

Ninety four field populations of *H. armigera* from 44 sites of north, central and south India were bioassayed with Cry1Ac during 1998 to 2005. However, the data indicated that susceptibility was found to be within the acceptable limits of the baseline, and did not indicate any shift in tolerance of *H. armigera* to Cry1Ac. Interestingly, resistance to Cry1Ac in field populations of any of the lepidopteran insect pests is yet to be detected in any part of the world, despite the fact that Bt transgenic cotton was being cultivated on a large scale in the U.S, China and Australia over the past several years.

Resistance management approaches generally rely on 1. conserving susceptibility by minimizing toxin exposure or 2. Getting rid of resistant RS and RR genotypes by using either high dose of the same toxin or by using other unrelated toxins.

In India an area of sprayed 20% refuge of non-Bt with Bt-cotton has been recommended by the GEAC. The stochastic model 'Bt-Adapt' developed at CICR, Nagpur (Kranthi and Kranthi, 2004) to understand and predict the rate of resistance development of *H. armigera* to Cry1Ac based Bt cotton showed that with 40% Bt cotton area in India, it would take at least 11 years for *H. armigera* Cry1Ac resistant allele frequency to reach 0.5, which would cause difficulties in pest control with Bt cotton. Stringent adherence to the 20% refugia, may give an additional 2 years advantage. However, if external pest control measures are taken to ensure that 90% of Bt-surviving larvae in Bt cotton with 50% bollworm control in non-Bt crops, it would take 70 and 45 years for resistant allele frequency to reach 0.5 with the Bt cotton area at 30 and 40% respectively.

## **Bollgard-II**

In 2006, the GEAC approved five Bollgard-II hybrids (from Ajeet, Krshidhan and Mahyco) for central India and two (from Mahyco) for south India. From a resistance management perspective, the strategy is good for resistance management, but would have been more advantageous if it would have been a simultaneous release, rather than one toxin first, followed by the mixture containing the toxin. The stacked genes are expected to increase the spectrum of toxicity to a wide range of lepidopteran insects to include *Spodoptera litura*, which is known to survive Cry1Ac.

GM crops under field testing, prospects for India and conclusion

In India, eleven crops (cotton, corn, brinjal, cabbage, cauliflower, ground nut, mustard, okra, pigeonpea, rice and tomato) have been genetically transformed for enhanced resistance to insects and viruses and are in various stages of testing. Six Cry (crystal) genes (*cry1Aa*, *cry1Ab*, *cry1Ac*, *cry1F*, *cry1B*, *cry2Ab*) and *vip-3A* gene from *Bacillus thuringiensis* were used for insect resistance in nine crops.

It is estimated that pests cause losses worth US \$ 120,000 million annually in India. Pesticides worth US \$ 8000 million are used every year in India. Cotton alone accounts for pesticides worth nearly US \$ 3800. The GM technology is expected to reduce at least 50% of the expenditure on pesticides. But most importantly, the yield increases due to reduction in crop damage is expected to result in benefits to the tune of at least US \$ 40,000. Therefore the novel technology of transgenic crops is being seen from a development perspective so as to ensure better socio-economic conditions for cultivators coupled with a healthier ecology and environment for the country.

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